

# Separation and Concentration of Alfalfa Juice Components by Dynamic Membrane Filtration

C. O'Donnell, R.G. Koegel and R.J. Straub

## Introduction

Value-added products, including industrially valuable enzymes are currently being produced in transgenic alfalfa by researchers at Madison, Wisconsin. One method of recovering the desired substances is from juice expressed from fresh herbage (wet fractionation). The juice contains both soluble and particulate components, largely broken chloroplasts.

Concentration of the protein in the whole juice by ultrafiltration has not been practical due to fouling and resultant flux reduction caused by the particulates. If the particulates are removed by some other means, such as centrifugation, ultrafiltration of the resulting clarified juice appears to work relatively well to concentrate the desired soluble proteins.

In the past, a technique for reducing filter blinding and fouling has been high tangential flow velocity of the feedstock in an attempt to scour the filter surface clean. This requires recirculating the feedstock many times at high velocity. The result is high power requirement, temperature rise of the feedstock, and possible degradation due to mechanical shear of the protein during many passes through the pump. An alternative is to have a filter surface moving at a high velocity with either rotational or oscillatory motion. This produces the desired relative motion between the filter surface and the feedstock in a more efficient way which should alleviate the problems of the conventional tangential flow filter.

The objective of this research is to assess whether dynamic membrane filtration could play a practical role in the concentration and/or fractionation of plant juice. In particular, could microfiltration remove particulates from the juice followed by ultrafiltration to concentrate the soluble protein in the resulting clarified juice?

## Methods

Filtration was carried out in a pilot apparatus (V-SEP) rented from New Logic International, Emeryville, CA.

Eleven-inch diameter filter membranes with nominal pore sizes ranging from a minimum of 10 kD (kilo Daltons  $\gg$  10,000 molecular weight cutoff) to a maximum of 3.0 mm (microns) were used. The membrane oscillated about its axis at a frequency of 60 Hz and an amplitude of 25 mm at the periphery. The flow rate or flux ( $\text{lm}^2\text{h}^{-1}$ ) and the fouling index ( $\text{FI} = \text{water flow rate}/\text{feedstock flow rate after two hours}$ ) were measured or calculated.

## Results

The results for a given set of filter operating conditions varied widely. It is recognized that the juice varies from day to day and that the physical properties of a given batch of juice can change with time, temperature, microflora, and mechanical shear. Figure 1 shows three different runs using identical membranes where the flux of the "best" run is approximately twice that of the "worst" run.

Table 1 shows that while the initial (water) flux ( $\text{F.I.} \times \text{J}$ ) of the larger pore sizes is great, the fouling index is also great, leading to greatly diminished flux at the end of two hours. Surprisingly, at the end of two hours the smallest pore size (10 kD) with the F.I. of 2 has the greatest two-hour flux (with one exception). It could be conjectured that the particles are too big to enter the very small pores and can thus be swept from the membrane surface by its motion. Figure 2 shows another example of a 10 kD membrane exhibiting a flux almost double that of a 1.0 mm membrane over an eight hour period.

Figures 3 and 4 show increase in phytase activity as juice dry matter is concentrated with time. Based on phytase molecule size, it might be expected that it would be retained by the 10 kD membrane, but passed into the permeate through the 0.1 mm membrane. It appears, however, to be retained by both membranes. This was subsequently confirmed by the low level of phytase activity found in both permeates. This phenomenon is believed to be due to a retained layer of material on the membrane surface

with an effective pore size smaller than that of the membrane. This could increase the difficulty of separating particulate from soluble protein.

### Conclusion

At the maximum flux of 100 l m<sup>-2</sup>h<sup>-1</sup> shown in Table 1, processing of 1 t juice per hour would require a filter area of 10 m<sup>2</sup>. One dynamic filter on the market has a maximum membrane area of approximately 30 m<sup>2</sup> and could thus be expected to process about 3 t/h of juice. It appears likely under present conditions that most of the soluble protein will be in the retentate regardless of membrane pore size.

In the future pretreatments of the juice, including thermal and pH adjustment will be evaluated in an attempt to aggregate the particulates into a coarser floc. This might allow use of a greater membrane pore size which might, in turn, lead to improvements in flux, lower fouling index, or permit separation of soluble protein from particulates.

Since membranes are expensive, an estimate of their total useful life needs to be made. This includes determining to what extent the original flux rate can be restored by cleaning techniques.

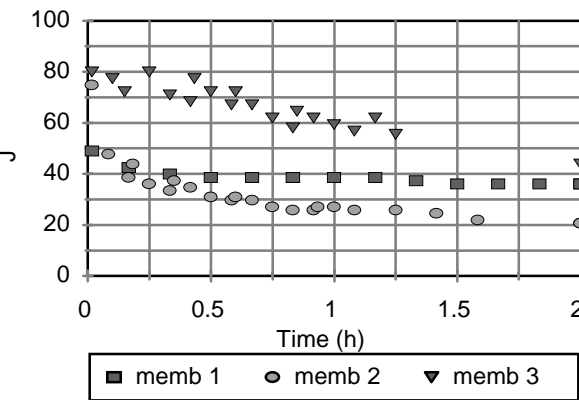


Figure 1. Flux (l/m<sup>2</sup>h) through 0.2mm membrane with permeate recycled.

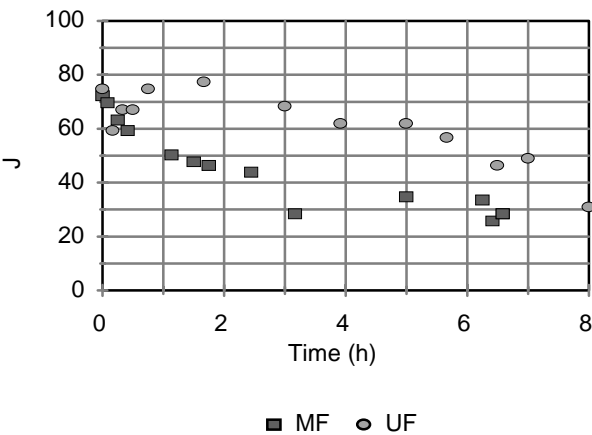


Figure 2. Flux (l/m<sup>2</sup>h) through 1.0 mm MF and 10 kD UF membranes for concentration of alfalfa juice expressing phytase.

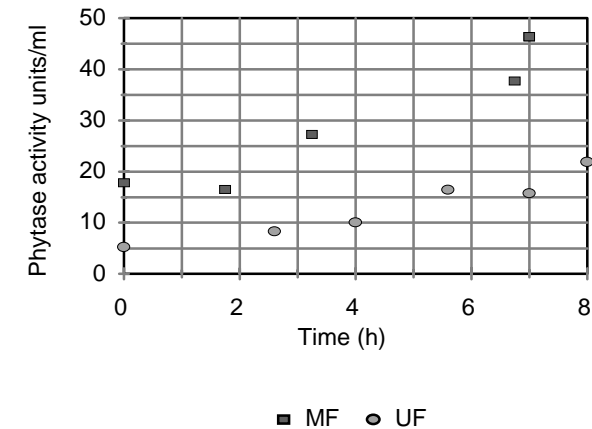


Figure 3. Phytase activity (U/ml) in the concentrated juice processed through 0.1 mm MF and 10 kD UF membranes.

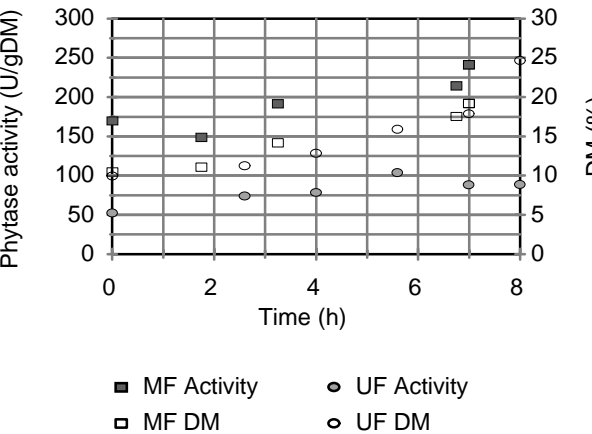


Figure 4. Phytase activity (U/gDM) and DM (%) in the concentrated juice processed through 0.1 mm MF and 10 kD UF membranes.

Table 1. Flux and fouling index of alfalfa juice.

Membrane		Flux, J, (lm <sup>2</sup> h <sup>-1</sup> )			Fouling Index		
Pore Size	h	max	min	mean	max	min	mean
3.0 mm	2	85.2	74.8	80.0	50	43	46.5
1.0 mm	4	139.4	32.3	69.7	83	40	58.8
0.5 mm	3	126.5	12.3	74.7	212	40	99.0
0.2 mm	3	43.9	20.6	33.5	116	54.5	78.8
0.1 mm	2	64.5	19.4	42.0	189	57	123
100 KD	2	55.4	51.6	53.5	10	9	9.5
10 KD	1	100.6	100.6	100.6	2	2	2